TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

DATA MANAGEMENT SYSTEM TECHNOLOGY DISCIPLINE

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TECHNOLOGY FOR SPACE STATION EVOLUTION -A WORKSHOP

DATA MANAGEMENT SYSTEM

DISCIPLINE ISSUES - SUMMARY

SYSTEMS - Improve Performance of EDP

STORAGE - Improve Mass Storage, Buffers and Block Storage

PROCESSORS - Evolutionary Integration of Multicomputers

ON BOARD COMMUNICATIONS - Increase Bandwidth of Existing Fibers

SOFTWARE - Expanded SSE with Tools and Guidelines for Verification

HUMAN INTERFACE - 3-D Display Technologies

MANAGEMENT - Must Approach SSF as an Integrated System, with System Wide V and V

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DATA MANAGEMENT SYSTEM

SYSTEMS TECHNOLOGY AREA NEEDS

NEEDS:

- HIGH PERFORMANCE COMPONENTS
- LOWER POWER COMPONENTS
- AUTOMATED SYSTEMS DIAGNOSIS
- SYSTEM (HW &SW) VERIFICATION
- FAULT TOLERANCE OVER LONG TERM WITH GRACEFUL DEGRADATION

ISSUES:

- HOW DO WE EVOLVE A SYSTEM?
- END-TO-END SYSTEMS ENGINEERING VS. END-TO-END SYSTEMS DESIGN

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DATA MANAGEMENT SYSTEM

STORAGE TECHNOLOGY AREA NEEDS

NEEDS:

- MASS STORAGE - BOTH BUFFER AND BLOCK ACCESS HIGH PERFORMANCE STAGED MEMORY SYSTEMS

ISSUES:

- OPTICAL DISK RECORDER NEARING TECHNOLOGICAL MATURITY

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DATA MANAGEMENT SYSTEM

PROCESSOR TECHNOLOGY AREA NEEDS

NEEDS:

- HIGH RATE SCIENCE PROCESSOR, IMAGE PROCESSOR, DATA COMPRESSOR
- EVOLUTIONARY INTEGRATION OF MULTICOMPUTERS
- SPECIAL-PURPOSE COPROCESSOR - NEURAL NETS

ISSUES:

- SIGNIFICANT IMPROVEMENTS IN SPEED/POWER IN EDP WOULD GREATLY HELP SSF

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DATA MANAGEMENT SYSTEM

COMMUNICATIONS TECHNOLOGY AREA NEEDS

NEEDS:

- METHODS TO UPGRADE PERFORMANCE OF FIBERS
- HIGHER RATES/THROUGHPUT

ISSUES:

- ACCOMMODATION NECESSARY TO PLAN FOR FIBER REPLACEMENT

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DATA MANAGEMENT SYSTEM *SOFTWARE SYSTEM TECHNOLOGY AREA NEEDS*

NEEDS:

- SSE DEVELOPMENT
- ABILITY TO PERFORM STAGE IMPLEMENTATION OF SOFTWARE

ISSUES:

- SOFTWARE VERIFICATION ... FORMAL PROOF VS. EXHAUSTIVE TESTING
- DISTRIBUTED DATA BASE ... ACCESS CONTROL, CONCURRENCY, DISTRIBUTION

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DATA MANAGEMENT SYSTEM

HUMAN INTERFACE TECHNOLOGY AREA NEEDS

NEEDS:

- 3-D DISPLAY TECHNOLOGIES FOR TELEROBOTIC AND COMPLEX DATA VISUALIZATION
- LARGE AREA, COLOR, FLAT PANEL DISPLAYS
- HIGH-RESOLUTION CAMERA INPUTS

ISSUES:

- STANDARD JOYSTICK AND INTERFACE FOR WORKSTATION

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DATA MANAGEMENT SYSTEM *SYSTEMS*

BACKGROUND

SCOPE - Higher performance, lower power system technologies that meet end-to-end system design requirements for a higher performance fault-tolerant, ultra-reliable DMS system.

OBJECTIVES - Develop end-to-end system models to analyze reliability, performance, power and latency requirements. Identify key system design parameters and develop and demonstrate system technologies to achieve the system requirement.

RATIONALE - Present and anticipate DMS requirements either stress DMS's capabilities or in fact exceed DMS's capabilities. NASA needs an end-to-end modeling and analysis capability to identify and analyze system requirements that are at risk.

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DATA MANAGEMENT SYSTEM *SYSTEMS*

PROGRAM PLAN

APPROACH:

1. ASSESS AND PROCURE TOOLS FOR MODELING AND ANALYZING END-TO-END SYSTEM REQUIREMENTS.

2. DEVELOP MODELS FOR END-TO-END SYSTEMS.

3. ANALYZE END-TO-END REQUIREMENTS AND IDENTIFY REQUIREMENT RISK AREAS AND POTENTIAL TECHNOLOGY ENHANCEMENT TO REDUCE RISK.

4. DEVELOP TECHNOLOGIES TO INCREASE PERFORMANCE, RELIABILITY, AND FAULT TOLERANCE.

5. IMPLEMENT A BRASSBOARD FOR HIGH PERFORMANCE, RELIABILITY, AND FAULT TOLERANT TECHNOLOGIES TO REDUCE REQUIREMENT SHORT FALLS.

6. DEMONSTRATE TECHNOLOGY COMPATIBILITY WITH DMS SYSTEM.

DELIVERABLES:

1. DEVELOP REQUIREMENT MODELS

2. TECHNOLOGY BRASSBOARDS

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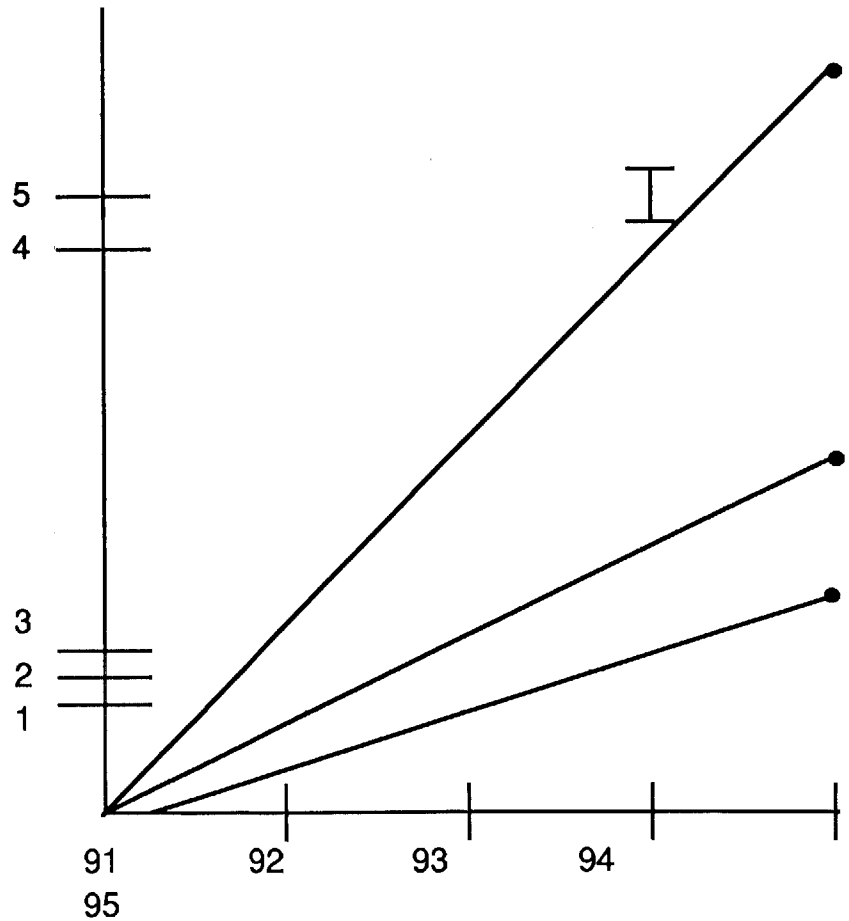
DATA MANAGEMENT SYSTEM *SYSTEMS*



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DATA MANAGEMENT SYSTEM *MASS STORAGE SYSTEM*

BACKGROUND

SCOPE:

RELIABLE HIGH-DENSITY MASS STORAGE THAT IS ABLE TO SUPPORT PHASE I PAYLOAD OPERATIONS ONBOARD AND PROVIDE AN EVOLVABLE BASIS FOR ENHANCED STORAGE TECHNOLOGIES REQUIRED TO ENABLE LATER PHASES OF STATION OPERATION AND HUMAN EXPLORATION OF THE MOON AND MARS.

OBJECTIVES:

TO DEVELOP THE KEY TECHNOLOGIES AND SYSTEM CONCEPTS AND DELIVER MASS STORAGE SYSTEMS ONBOARD SPACE STATION FREEDOM THAT WILL PROVIDE ON-LINE RAPID ACCESS CAPACITY TO SYSTEM AND PAYLOAD USERS. TO EVALUATE AND DEVELOP NEW STORAGE TECHNOLOGIES AS WELL AS ENHANCED VERSIONS OF THE SSF SYSTEMS TO SATISFY THE REQUIREMENTS ON THE HEI.

RATIONALE:

THE PRESENT MASS STORAGE SYSTEM PROPOSED FOR SSF PROVIDES INADEQUATE STORAGE FOR BUFFERING PAYLOAD DATA FOR DELAYED PROCESSING AND/OR TRANSMISSION. SOME OF THE PAYLOADS REQUIRE TERABYTE DATA CAPACITY AND EXTREMELY HIGH INGEST RATES. ENHANCED STORAGE PROVIDED BY VARIOUS TECHNOLOGIES IS ESSENTIAL TO REDUCE THE LOAD ON RESTRICTED DOWNLINK CAPABILITY AND TO ALLEVIATE THE UNACCEPTABLE SITUATION OF SCHEDULING PAYLOAD ACTIVITIES AROUND DATA TRANSMISSION AVAILABILITY. DATA REQUIREMENTS FOR LATER PHASES OF STATION OPERATION, LUNAR EXPLORATION AND THE MISSION TO MARS WILL BE MORE STRINGENT THAN THOSE OF THE PMC.

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DATA MANAGEMENT SYSTEM *MASS STORAGE SYSTEM*

PROGRAM PLAN

RECOMMENDATIONS/ISSUES:

SEVERAL OF THE TECHNOLOGIES THAT CAN ENABLE PAYLOAD OPERATIONS ON SPACE STATION FREEDOM CAN BE MADE READY IN THE NEAR TERM. FOR EXAMPLE, WORK IN THE AREAS OF REWRITABLE MAGNETO-OPTIC DISK TECHNOLOGY IS AT LEVEL 3 AND IS READY TO BE INCORPORATED INTO A FLIGHT EXPERIMENT AND QUALIFIED. THE FURTHER DEVELOPED TECHNOLOGIES DO NOT "DEAD-END" ON THE STATION, THEY CAN BE ENHANCED SERVE INTO THE HEI ERA. THE OTHER YOUNGER TECHNOLOGIES SHOULD BE PURSUED AS THEY TOO CAN OFFER BENEFITS LATER IN THE HEI.

MAJOR CHALLENGES FOR ALL THESE TECHNOLOGIES INCLUDE THE USUAL SPACEFLIGHT CONSTRAINTS OF WEIGHT, POWER, AND VOLUME AS WELL AS RELIABILITY, MAINTAINABILITY, AND EVOLVABILITY REQUIRED FOR THE LONG-TERM MISSIONS.

A SUITE OF TECHNOLOGIES MUST BE EVALUATED, BECAUSE NO ONE TECHNOLOGY CAN MEET THE SPECTRUM OF USER REQUIREMENTS (E.G., DATA RATE, CAPACITY).

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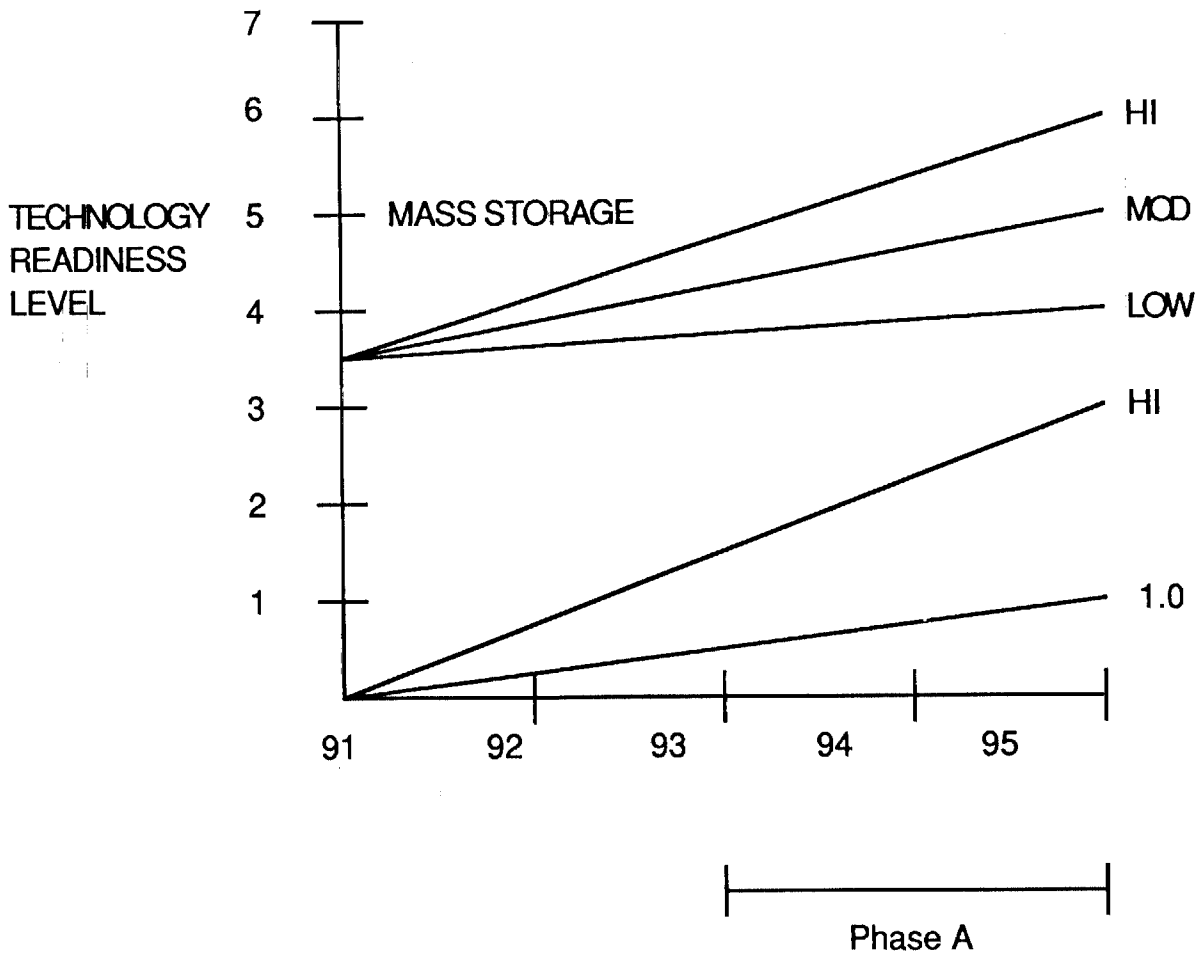
TECHNOLOGY ASSESSMENT *MASS STORAGE STYSTEM*

TECHNOLOGY ASSESSMENT



TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

DATA MANAGEMENT SYSTEM *PROCESSORS*

BACKGROUND

SCOPE:

SPECIAL- AND GENERAL-PURPOSE COMPUTER AND OPERATING SYSTEMS TECHNOLOGIES TO ENABLE ENHANCED ONBOARD DATA PROCESSING AND CONTROL.

OBJECTIVES:

TO DEMONSTRATE THE CAPABILITY TO REPLACE GENERAL-PURPOSE PROCESSORS ONBOARD THE STATION WITH MULTIPROCESSOR BASED ON ADVANCED COMPONENTS WHICH WILL PERFORM THE EXISTING FUNCTIONS AND, IN ADDITION, INCLUDE SIGNIFICANT CAPABILITY FOR EXPANSION; TO DEMONSTRATE HIGHLY PARALLEL PROCESSORS CAPABLE OF HIGH THROUGHPUT IMAGE AND SCIENCE DATA PROCESSING; AND TO DETERMINE AND DEMONSTRATE THE APPLICABILITY OF SPECIAL PROCESSING ARCHITECTURES FOR NEURAL AND SYMBOLIC PROCESSING TO SPACE STATION TASKS.

RATIONALE:

CURRENTLY, OAST IS FUNDING SEVERAL GENERIC PROCESSOR TECHNOLOGY DEVELOPMENTS. THESE DEVELOPMENTS, TOGETHER WITH COMMERCIAL AND DOD DEVELOPMENTS, WILL PRODUCE SPECIAL- AND GENERAL-PURPOSE COMPUTING TECHNOLOGIES WHICH COULD YIELD A TEN-FOLD INCREASE IN ONBOARD COMPUTING CAPABILITY WITH NO INCREASE IN ELECTRICAL POWER REQUIREMENTS. A SIGNIFICANT CAPABILITY INCREASE IS NEEDED TO SUPPORT INCREASE SCIENCE USAGE, TO SUPPORT ASSEMBLY AND ON-ORBIT CHECKOUT, AND TO REDUCE CREW TIME REQUIRED FOR DIAGNOSIS AND MAINTENANCE. BEFORE THESE ADVANCED TECHNOLOGIES CAN BE USED ON SPACE STATION FREEDOM, HOWEVER, THEY MUST BE MADE COMPATIBLE WITH THE STATION'S EXISTING HARDWARE, SOFTWARE, AND DEVELOPMENT AND SUPPORT ENVIRONMENTS. IN ADDITION, FOR THE SPECIAL-PURPOSE PROCESSORS, ALGORITHMS AND ARCHITECTURES APPROPRIATE TO KEY SPACE STATION NEEDS MUST BE DEVELOPED AND DEMONSTRATED.

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

DATA MANAGEMENT SYSTEM *PROCESSORS*

PROGRAM PLAN

APPROACH:

1. DEMONSTRATE A BREADBOARD/BRASSBOARD MULTIPROCESSOR EDP UPGRADE PERFORMING A SELECTED SET OF DMS SOFTWARE AND APPLICATIONS INTEGRATED IN THE GROUND-BASED DMS TESTBED. (THIS PLAN ASSUMED ADEQUATE SUPPORT UNDER CSTI DATA SYSTEMS TO DEVELOP THE MULTIPROCESSOR AND ITS OPERATING SYSTEM.)

2. DEVELOP AND DEMONSTRATE A HIGHLY PARALLEL IMAGE AND SCIENCE DATA PROCESSOR BRASSBOARD PERFORMING SIMULATE STATION DATA REDUCTION TASK. (ASSUMES CSTI DATA SYSTEMS ADVANCED IMAGE PROCESSOR)

3. DEMONSTRATE THE CAPABILITY TO INTEGRATE FRONT-END SIGNAL PROCESSING ON FOCAL-PLANE SENSORS.

4. DEVELOP NEURAL AND/OR SYMBOLIC PROCESSING ARCHITECTURES FOR SPECIFIC SSF APPLICATIONS TO DEMONSTRATE THE FEASIBILITY AND EFFECTIVENESS OF USING THESE INNOVATIVE APPROACHES.

DELIVERABLES:

1. DEMONSTRATE EDP UPGRADE BRASSBOARD INTEGRATED INTO THE SPACE STATION INTEGRATED TESTBED.

2. BRASSBOARD DEMONSTATION OF HIGHLY PARALLEL IMAGE DATA PROCESSING.

3. TEST DEVICE INTEGRATING FRONT-END SIGNAL PROCESSING WITH FOCAL-PLANE SENSORS.

4. BREADBOARD DEMONSTRATION OF A NEURAL PROCESSING APPLICATION IN ROBOTICS, STRUCTURE CONTROL, DATA ANALYSIS, OR PLANNING ASSISTANCE.

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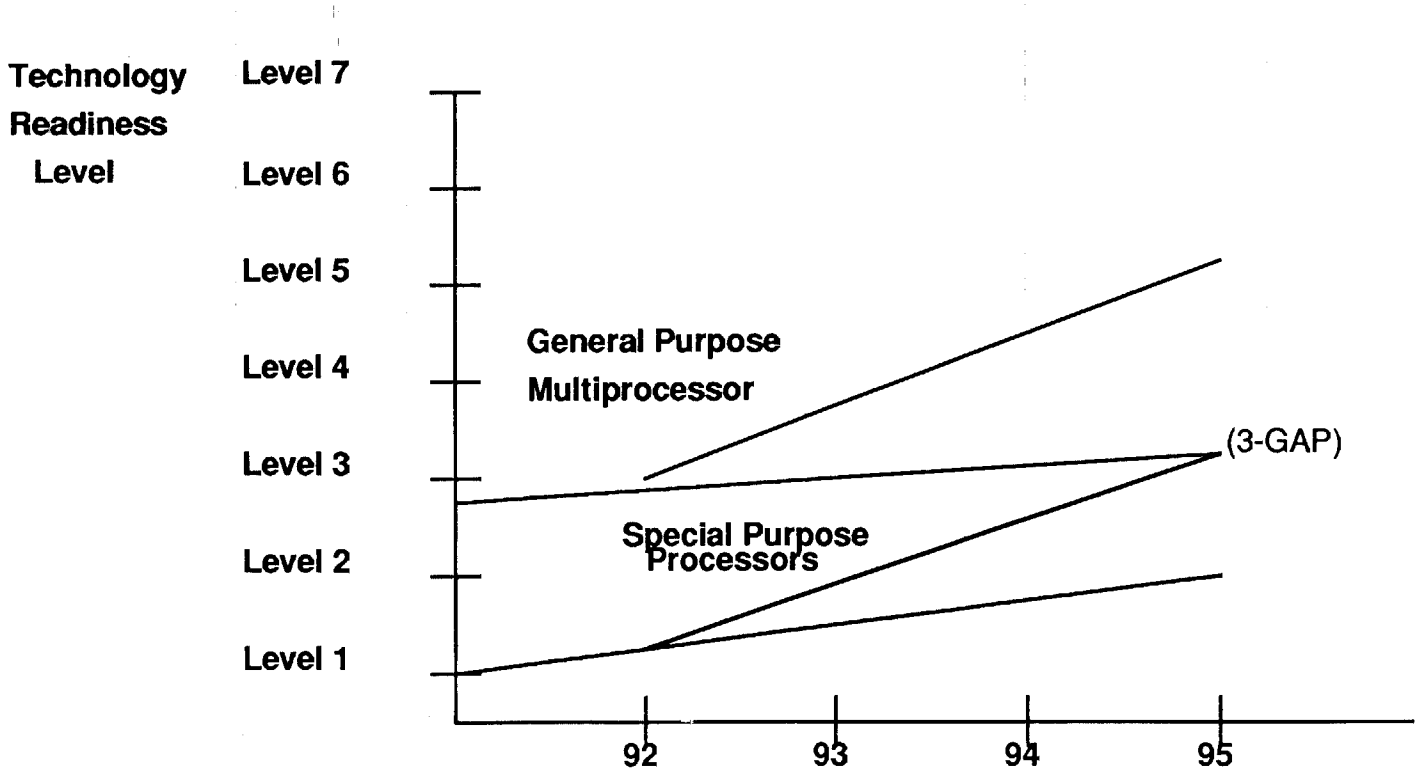
DMS *PROCESSORS*

TECHNOLOGY ASSESSMENT



TECHNOLOGY FOR SPACE STATION EVOLUTION - WORKSHOP

DATA MANAGEMENT SYSTEM *SOFTWARE DEVELOPMENT AND VERIFICATION*

BACKGROUND

SCOPE:

AN EXPANDED SSE THAT INCLUDES TOOLS AND GUIDELINES FOR SOFTWARE VERIFICATION, SOFTWARE METRICS AND ANALYSIS, SSE PERFORMANCE AND UTILIZATION METRICS, AN ENHANCED REUSABLE LIBRARY LINKED TO DESIGN SUPPORT AIDS, AND SUPPORT FOR MANAGEMENT AND CONTROL OF DISTRIBUTED DATABASE OF SSFP SOFTWARE OBJECTS (DESIGN REPRESENTATIONS, SOURCE CODE SEGMENTS, OBJECT CODE PACKAGES, TEST PROCEDURES AND DATA).

OBJECTIVES:

TO DEVELOP ENHANCEMENTS TO THE SSE THAT ADDRESS SOME AREAS CURRENTLY DEFERRED DUE TO BUDGET AND TECHNOLOGY CONSTRAINTS BUT WHICH WILL GREATLY IMPROVE THE SOFTWARE DEVELOPMENT AND VERIFICATION PROCESS FOR FUTURE SPACE STATION SOFTWARE.

RATIONALE:

THE SSE IS BEING DEVELOPED TO SUPPORT SOFTWARE DEVELOPMENT AND SSF LIFE-CYCLE SOFTWARE SUPPORT AND TO ENCOURAGE USE OF COMMON SOFTWARE ELEMENTS. THE INITIAL SSE IS PRIMARILY A COLLECTION OF COTS WITH SOME SUPPORTING SOFTWARE. THE SSE PROJECT IS FOCUSED ON MEETING THE IMMEDIATE NEEDS OF THE WP CONTRACTORS. THE ISSUES OF SOFTWARE VERIFICATION, SOFTWARE METRICS, AND A DISTRIBUTED REUSABLE LIBRARY WILL RECEIVE LITTLE ATTENTION IN THE NEAR TERM. METHODS ARE NEEDED TO INSURE SSF SOFTWARE WILL PERFORM AS EXPECTED WITHOUT DEPENDING ON THE PROHIBITIVELY EXPENSIVE, EXTENSIVE TESTING METHODS CURRENTLY EMPLOYED FOR THE SHUTTLE ORBITER.

TECHNOLOGY FOR SPACE STATION EVOLUDTION - A WORKSHOP

DATA MANAGEMENT SYSTEM *SOFTWARE DEVELOPMENT AND VERIFICATION*

PROGRAM PLAN

APPROACH:

1. DEVELOP AN INTEGRATED TEST SUITE TO SUPPORT SOFTWARE VERIFICATION TESTING INCLUDING GUIDELINES ON HOW TO APPLY THE SPECIFIC TOOLS. THIS SUITE WILL INCLUDE COTS TOOLS AND EXISTING SSE TOOLS WHEN POSSIBLE.

2. SELECT AN APPLICATION FROM SSF AND APPLY A FORMED SPECIFICATION AND VERIFICATION AND COMPARE EFFORT AND RESULTING CONFIDENCE WITH THE STANDARD METHODOLOGY USED FOR THE SAME APPLICATION BY THE SSFP SOFTWARE DEVELOPERS.

3. SELECT A SET OF SOFTWARE METRICS, INSTRUMENT THE SSE TO COLLECT THESE METRICS FOR SSE PERFORMANCE AND OPERATION, INSTALL THESE INSTRUMENTS IN A SPECIFIC OPERATIONAL SPF, COLLECT THESE METRICS OVER AT LEAST A 30-DAY OPERATIONAL PERIOD, ANALYZE THE RESULTS, AND MODIFY THE DATA COLLECTION AND METRICS TECHNIQUES AND REPEAT THE EXPERIMENT.

4. INVESTIGATE DISTRIBUTED DATABASE MANAGEMENT TECHNIQUES AND IDENTIFY THOSE WHICH ARE APPROPRIATE FOR MANAGING A DISTRIBUTED SOFTWARE LIBRARY. DEVELOP A PROTOTYPE DISTRIBUTED LIBRARY MANAGEMENT AND DEMONSTRATE THE UTILITY OF THESE TECHNIQUES FOR CONTROLLING ACCESS, INTEGRITY ASSURANCE, DISTRIBUTION, AND DATA UPDATE. INVESTIGATE PERFORMANCE ISSUES AND POSSIBLE REQUIREMENTS FOR LOCAL (DUPLICATE) COPIES OF ACTIVE DATA AND METHODS FOR MAINTAINING INTEGRITY OF ALL COPIES.

5. BUILD A PROTOTYPE SYSTEM WHICH COMBINES CASE TOOLS WITH A LIBRARY BROWSER TO SERVE AS A DESIGNER'S AID COUPLED TO A REUSE LIBRARY.

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

DATA MANAGEMENT SYSTEM *SOFTWARE DEVELOPMENT AND VERIFICATION*

PROGRAM PLAN
(CONTINUED)

DELIVERABLES:

1. DOCUMENT THE GUIDELINES FOR INTEGRATED TESTING FOR SOFTWARE VERIFICATION. IDENTIFY ADDITIONAL TEST TOOLS TO BE ADDED TO SSE TOOLSET TO ENHANCE SOFTWARE VERIFICATION.

2. REPORT ON THE APPLICATION OF FORMAL VERIFICATION TO THE SPECIFIC SSFP APPLICATION SELECTED, INCLUDING COMPARISON OF THE EFFORT REQUIRED AND RESULTING QUALITY OF SOFTWARE.

3. (A) REPORT ON SELECTED SOFTWARE METRICS AND RESULTS OF EXPERIMENTS WITH INSTRUMENTED SSE.

   (B) RECOMMENDATIONS FOR SOFTWARE METRICS TO BE COLLECTED DURING SSFP SOFTWARE DEVELOPMENT AND SPECIFIC METRIC ANALYSIS TOOLS TO BE ADDED TO SSE TOOLSET.

   (C) DRAFT GUIDELINES FOR USE OF SOFTWARE METRIC TOOLS.

   (D) RECOMMEND CHANGES TO SSE TO IMPROVE PERFORMANCE OF THE SSE BASED ON THE SOFTWARE METRICS ANALYSIS.

4. DEMONSTRATE PROTOTYPE DISTRIBUTED LIBRARY SYSTEM. RECOMMEND TECHNIQUES TO ENHANCE SSE LIBRARY SYSTEM.

5. DEMONSTRATE PROTOTYPE DESIGN/LIBRARY SYSTEM TO ILLUSTRATE ENHANCED REUSE LIBRARY SYSTEM APPROACH.

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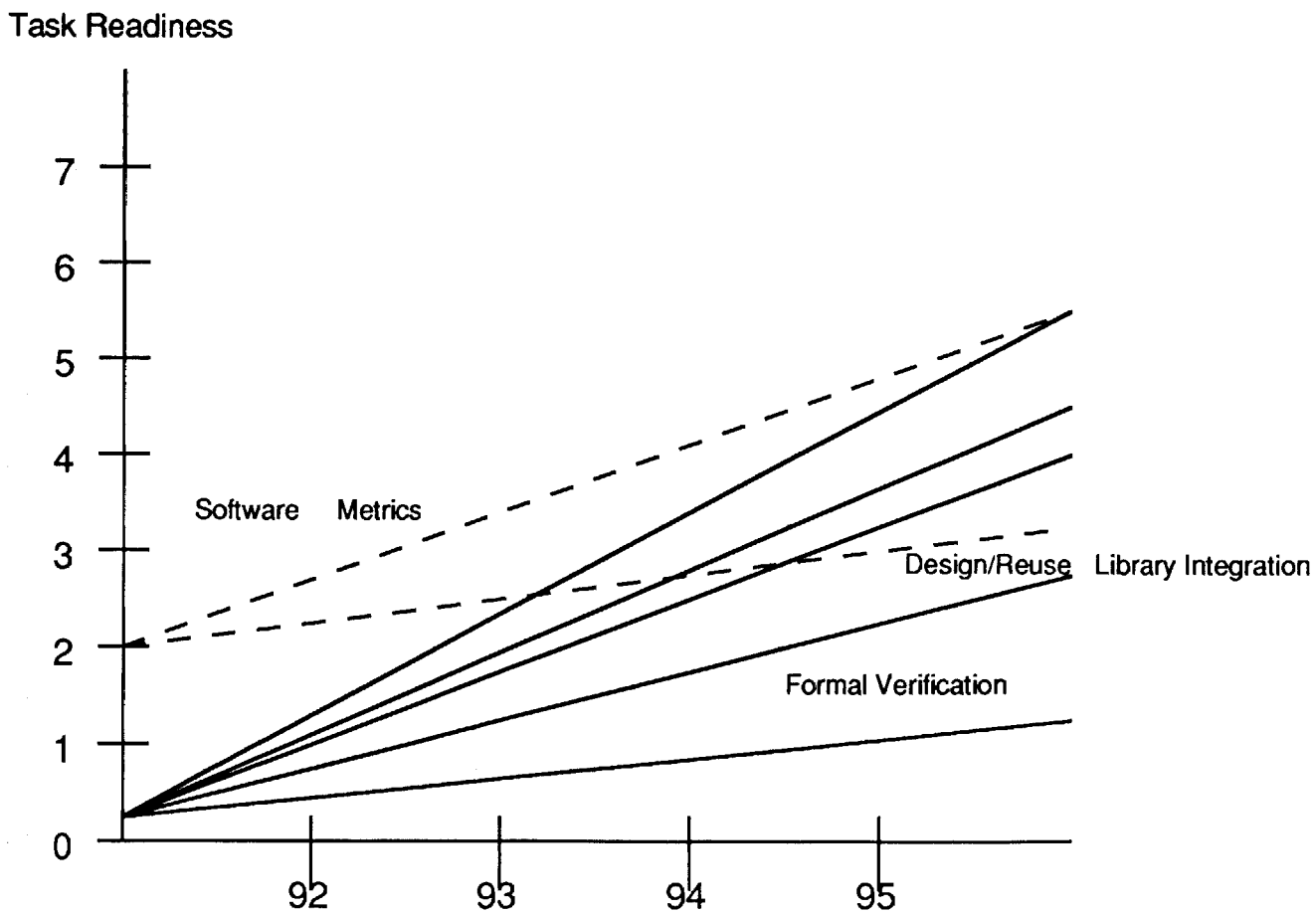
DATA MANAGEMENT SYSTEM *SOFTWARE DEVELOPMENT AND VERIFICATION*

TECHNOLOGY ASSESSMENT



TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

DATA MANAGEMENT SYSTEM *ONBOARD COMMUNICATIONS*

BACKGROUND

SCOPE:

UPGRADE THE DMS DATA RATE HANDLING CAPABILITY INDEPENDENT OF THE FIBER-OPTIC CABLE LIMITATION BY USING EMERGING NEW TECHNOLOGY TO SUPPORT HARDWARE PAYLOADS AND SYSTEM UPGRADES.

OBJECTIVES:

TO DEVELOP METHODS OF INCREASING THE DMS DATA RATE CAPACITY OVER THE FIBER-OPTIC CABLE LIMITATION TO SUPPORT HIGH-RATE SCIENCE AND TO ENABLE DMS USERS TO INCREASE THEIR DMS REQUIREMENTS AS NEW TECHNOLOGY IS IMPLEMENTED.

RATIONALE:

THE DMS COMMUNICATION RATE IS LIMITED BY THE FIBER-OPTIC CABLE CAPACITY, AND THE ABILITY TO UPGRADE THE FIBER-OPTIC CABLE IS NOT PRACTICAL DUE TO INACCESSABILITY. ANY TECHNOLOGY UPGRADE IN THE DMS COMPONENTS WILL BE LIMITED THE FIBER-OPTIC CABLE DATA RATE CAPACITYL.

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

DATA MANAGEMENT SYSTEM *ONBOARD COMMUNICATIONS*

PROGRAM PLAN

APPROACH:

1. INVESTIGATE METHODS OF MODULATION ON A SINGLE FIBER THAT WOULD ENABLE INCREASED INFORMATION CAPACITY WITHOUT INCREASING THE CLOCK RATE.

2. INVESTIGATE THE USE OF MULTIPLE FIBER OPTIC CABLE CONFIGURATIONS THAT WOULD INCREASE THE DMS DATA RATE CAPACITY.

3. INVESTIGATE THE USE OF NON-FIBER OPTIC COMMUNICATION METHODS SUCH AS LASER LINKS TO WIRE AS THE DMS DATA RATE CAPACITY.

DELIVERABLES:

1. DEMONSTRATE A MODUALTION SCHEME THAT INCREASES THE DATA RATE CAPACITY OVER EXISTING FIBER OPTIC CABLES.

2. DEMONSTRATE A MULTIPLE FIBER OPTIC CONFIGURATION USING ALL OF THE EXISTING FIBER OPTIC CABLES THAT INCREASES THE DATA RATE CAPACITY.

3. DEMONSTRATE A NON-FIBER COMMUNICATION SYSTEM THAT INCREASES THE DATA RATE CAPACITY.

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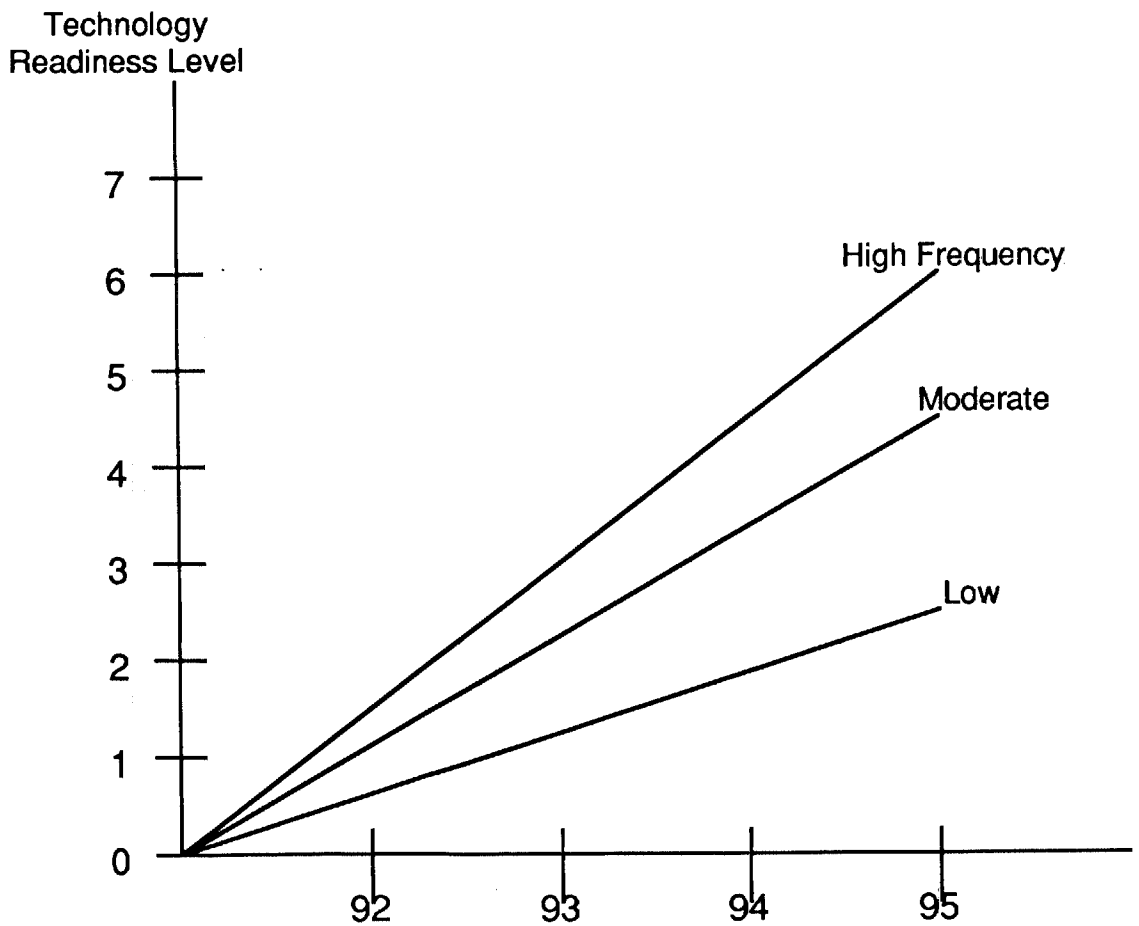
DATA MANAGEMENT SYSTEM

ONBOARD COMMUNICATIONS



TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

RECOMMENDATIONS / ISSUES

- APPROACH SSF AS AN INTEGRATED SYSTEM
- BETTER INTERPERSONAL COMMUNICATIONS
  - NEED: STANDARD, CONTROL, ENFORCEMENTS
  - NEED: MULTIPLE SYSTEM INTEGRATION FACILITY
- SYSTEM RETIREMENT ISSUES
  - SOFTWARE, HARDWARE, CUTOVERS
  - FLIGHT PROCESSOR EVOLUTION ... COMMERCIAL/DOD/SDIO
- SSIS TO C&T TO DMS NOT DISCUSSED
- A PROVISION OR MECHANISM FOR SRU LEVEL REPLACEMENT ON BOARD
- NEED ACCOMMODATION TO ALLOW UPGRADE/REPLACE FIBERS ON GLOBAL NET AND HIGH RATE LINKS

DMS OPPORTUNITIES

- AI MAINTENANCE ASSISTANT SUBSYSTEM ... AI AUGMENTED TESTS
- OVERLAY OF DATA AND VIDEO, MIXED GRAPHICS, DIGITAL HDTV, ANIMATED GRAPHICS

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